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3. Full name, address and postcode of the or of each applicant (underline all surnames)Downhole Products plc
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Murgitroyd & Company

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1 "Apparatus"

2

3 The present invention relates to apparatus for
4 mobilising drill cuttings in an oil or gas well.

5

6 The art of drilling wellbores for recovery of oil
7 and gas is well known. One particular problem faced
8 by this art is the removal of cuttings from the well
9 as they are generated by the action of the drill bit
10 cutting into the formation. The cuttings need to be
11 removed from the bit and conveyed back to surface as
12 efficiently as possible, as their persistence in the
13 wellbore hampers drilling activity, and tends to
14 reduce the productivity of the well.

15

16 Cuttings are washed back to surface by drilling mud
17 or fluid pumped down the string, out through the
18 bit, and back up the annulus surrounding the string.
19 This solution is generally satisfactory, but in long
20 and deviated wells we have found that cuttings still
21 tend to clump and impede the drilling activity, or
22 the production of the well.

1 According to the present invention there is provided
2 apparatus for mobilising drill cuttings in a well,
3 the apparatus comprising at least one vane, and two
4 or more blades defining at least one fluid conduit
5 between adjacent blades, the blades and vane being
6 rotatable relative to one another.

7
8 Typically the blades are configured to create a
9 pressure difference in fluid flowing through the
10 conduit, but this is not essential, and a fluid
11 drop, if required, can be induced by other means
12 apart from the blades.

13
14 The apparatus typically comprises a sleeve or
15 collar, which is typically tubular and is adapted to
16 fit over a string in the well. The string can be a
17 tubing string, drill string, or casing string etc.
18 Typically the vanes are provided on the sleeve.

19
20 Typically the blades are mounted on a bushing that
21 is rotatably mounted on the sleeve.

22
23 However, in certain simple embodiments, it is
24 sufficient to provide the vanes direct on the tubing
25 string (or on a sleeve attached to the string) and
26 to provide the blades on an adjacent part of the
27 string, or on a separate sleeve attached thereto, so
28 that the blade-bearing bushing is not directly
29 attached to the vane-bearing sleeve. The blades or
30 the bushing can optionally be incorporated into a
31 sub in the string, or on a collar that is separately
32 attached to the string.

1 Typically the sleeve is adapted for attachment to a
2 drill string, and the fixing means typically
3 comprises a clamp means such as an annular clamp to
4 fix the sleeve over the outer surface of the drill
5 pipe. However, the sleeve may equally attach to
6 casing or any other oilfield tubular goods.

7
8 The vanes can be carried direct on the sleeve, or in
9 some embodiments can be provided on a separate
10 bushing rotationally (or otherwise) affixed to the
11 sleeve. The vanes typically rotate with the drill
12 string in normal rotary drilling operations as they
13 are typically rotationally fixed to the drill
14 string. The rotation of the vanes agitates the
15 fluid surrounding the apparatus, and creates thrust
16 tending to drive the fluid past the sleeve.

17 The blades of the bushing typically create a
18 pressure drop in the fluid as it flows past the
19 apparatus, driven by the rotation of the vane(s).

20
21 Typically the bushing is free to rotate relative to
22 the sleeve, which is affixed to the drill string.
23 Thus, upon rotation of the drill string (or casing)
24 during normal rotary drilling, the bushing typically
25 remains stationary relative to the wellbore, while
26 the drill string rotates.

27
28 Typically the blades on the bushing project radially
29 outward to a greater extent than the vanes of the
30 sleeve, so that the radially outermost surface of
31 the blades contacts the inner surface of the bore
32 within which the string is located, and this

1 centralises the sleeve within the bore. In
2 preferred embodiments, the vanes are radially lower
3 than the blades, and can freely rotate within the
4 bore, as the higher blades provide a stand off against the inner surface of the
5 bore. The bore can be the unlined wellbore, or can
6 be the bore of casing, liner or other tubing in
7 which the apparatus is located.
8

9
10 The blades can be set parallel to the axis, or can
11 be offset with respect to it, so that they extend
12 helically around the bushing. In some embodiments
13 the blades are offset at an angle of 3-10° e.g. 5°
14 from top left to bottom right with respect to the
15 axis of the bushing. This orientation is useful in
16 drillstrings that are conventionally rotated to the
17 right, as the fluid path up the annulus tends to
18 flow in a spiral from bottom right to top left at
19 around 5° off the axis. Therefore, the offset
20 blades do not substantially impede the fluid flow
21 rate. Clearly adjustments can be made to the offset
22 angle to suit the fluid flow direction in other
23 wells.
24

25 The blades typically have an asymmetric profile, and
26 in preferred embodiments the blades are shaped in
27 the form of foils, so that the fluid conduits
28 defined between adjacent blades on the bushing
29 change in profile. Typically the fluid conduits are
30 relatively narrow at a lower end (nearest the drill
31 bit) and grow relatively wider toward the upper end
32 (furthest away from the bit). The increase in

5

1 dimension from the bottom of the channel to the top
2 causes a pressure drop in the fluid flowing through
3 the channel.

4

5 The blades can have profiled cross sections (i.e.
6 end-on view) in the form of an hour glass, with a
7 wide root radially innermost adjacent the bushing,
8 a wide top at the radially outermost part of the
9 blade that bears against the borehole wall, and a
10 narrower cutaway portion between the two to
11 facilitate fluid flow between the blades. This
12 cutaway creates more space for the fluid to pass
13 between the blades, and helps to avoid impedance of
14 the fluid flow.

15

16 Typically the bushing can be formed from a rigid
17 material, such as hard rubber or metal. The sleeve
18 is typically formed from metal such as steel, alloy,
19 aluminium, etc.

20

21 The sleeve can have an annular body to fit around a
22 tubular or string of tubulars. The annular body can
23 have the vanes integrally formed with it, for
24 example by moulding the sleeve and vanes as a single
25 piece. In alternative (and preferred) embodiments,
26 the sleeve can have vane-receiving recesses therein
27 to receive and retain modular vanes, which can be
28 slotted in the recesses, and retained therein. This
29 has the advantage that several different sizes of
30 vanes can be used with a single sleeve.

31

1 Likewise, the blades on the bushing can be modular
2 and can be received within blade recesses in the
3 same manner.

4
5 The vanes can be curved or straight, and can lie
6 parallel to the axis, but in typical embodiments
7 they cross the axis of the sleeve so as to scoop the
8 fluid from the annulus. The lower end of the vane
9 is typically circumferentially spaced around the
10 sleeve from the upper end, typically in the
11 direction of rotation of the string, so where the
12 string rotates to the right (as is conventional in
13 most wells) the vanes are offset across the axis
14 from top right to bottom left, the opposite
15 configuration from the offset blades described
16 above.

17
18 In some embodiments the vanes are configured in a
19 sinusoidal "lazy-s" shape and this helps to agitate
20 the fluid surrounding the apparatus during rotation.
21 In other embodiments, they are disposed straight
22 across the axis.

23
24 The vanes can have concave surfaces to assist in the
25 scooping action, and typically the concave surfaces
26 can be provided in one side of the vane only,
27 typically on the side of the vane facing the
28 direction of rotation. The concave surface can be
29 regular and unchanging along the side of the vane,
30 but in some embodiments the side vane is shaped to
31 have more of a curve on its upper end than on its
32 lower end, so that as the fluid moves up the side of

1 the vane, the increasing curve of the concave
2 surface keeps the fluid close to the sleeve, where
3 most turbulence will be generated, thereby keeping
4 the cuttings in suspension for longer.

5
6 The invention also provides a drill cuttings
7 agitation assembly, comprising a tubular, a vane,
8 and at least two blades defining at least one fluid
9 conduit between adjacent blades, wherein the vane
10 and the blades are rotatable relative to one
11 another.

12
13 The invention also provides a method of agitating
14 drill fluid in an oil or gas well, the method
15 comprising passing the drill fluid past a vane
16 rotatable relative to at least two blades.

17
18 An embodiment of the invention will now be described
19 by way of example and with reference to the
20 accompanying drawings, in which:

21
22 Fig. 1 is a side view of apparatus according to
23 the present invention, mounted on a tubular;
24 Fig. 2 is a close up side view of the Fig 1
25 apparatus;
26 Fig. 3 is a side view of a sleeve of the Fig 1
27 apparatus;
28 Fig. 4 is a side view of a bushing of a bushing
29 of the Fig 1 apparatus;
30 Fig. 5 is a side view of a clamp of the Fig 1
31 apparatus;

1 Figs. 6 and 7 (respectively) plan and underside
2 views of the Fig 4 bushing;
3 Fig. 8 is a flat view of a bushing half shell;
4 Fig. 9 is a side view of a bushing blade;
5 Fig. 10 is a plan view of a sleeve;
6 Fig. 11 is a sectional view through a clamp;
7 Fig. 12 is an outer side view of a second
8 sleeve;
9 Fig. 13 is an inner side view of the second
10 sleeve;
11 Fig. 14 is a sectional view through the second
12 sleeve;
13 Fig. 15 is a perspective view of a modular vane
14 for the second sleeve;
15 Fig. 16 is an underneath view of the Fig 15
16 vane;
17 Fig. 17 is a plan view of the Fig 15 vane;
18 Fig. 18 is a side view of the same vane;
19 Fig. 19 is a side view of a second embodiment
20 of apparatus mounted on a tubular;
21 Fig. 20 is a sectional view from beneath the
22 Fig 19 apparatus at point A;
23 Fig 21 is a sectional view from beneath the
24 Fig 19 apparatus at point B;
25 Fig 22 is a plan of a vane; and
26 Fig. 23 is a plan view of a second vane
27

28 Referring now to the drawings, apparatus for
29 mobilising drill cuttings in a well comprises a
30 sleeve 5, a bushing 7 and a clamp 9. All of these
31 components are generally tubular, but are axially
32 divided into two separate leaves that are hinged

1 together. The leaves of the sleeve 5 are hinged at
2 three locations 5h, and its two leaves pivot around
3 those hinges to enable the sleeve 5 to be opened and
4 closed around a tubular T such as drill pipe or
5 casing. The two halves of the sleeve are locked
6 together by one or more bolts 5b at a position
7 diametrically opposite to the hinge 5h, so that the
8 sleeve 5 can be tightly fastened to the tubular T by
9 means of the bolts.

10

11 The hinges 5h are located on an upper part of the
12 sleeve 5, beneath which is a bearing region 6 having
13 a reduced outer diameter as compared with the
14 nominal diameter of the upper region. An annular
15 groove 6g is formed on the lower end of the bearing
16 region 6, and a shoulder 6s divides the upper and
17 bearing regions of the sleeve.

18

19 The bushing 7 is also formed as two separate leaves
20 that are connected together at diametrically opposed
21 positions by interlocking castellations and
22 connecting pins 7p, about which the two leaves can
23 pivot. The two leaves of the bushing 7 are
24 typically closed around the bearing region 6 of the
25 sleeve, at which point the leaves are connected
26 together by inserting the pins 7p into axially
27 aligned bores on the interlocking castellations to
28 close and lock the bushing 7, so that the bushing 7
29 is connected to the sleeve 5.

30

31 After the bushing 7 has been locked in place around
32 the bearing region 6 of the sleeve 5, the clamp 9 is

1 then placed around the lower end of the bearing
2 region 6, so that an annular lip on the internal
3 surface of the clamp 9 engages in the external
4 annular groove 6g on the lower part of the bearing
5 region 6. The clamp 9 is then closed and fastened
6 by means of bolts (not shown) in the same manner as
7 the bolts 5b that lock the sleeve closed around the
8 tubular T.

9
10 When thus assembled, the tightening of the bolts in
11 the sleeve 5 and the clamp 9 securely connects the
12 sleeve to the tubular, so that the two are
13 rotationally connected, and thus the sleeve rotates
14 with the tubular.

15
16 The bushing 7 is fixed to the bearing area 6 of the
17 sleeve, and is prevented from axial movement by the
18 shoulder 6s above it, and the clamp 9 below it;
19 however, the bushing 7 is free to rotate around its
20 axis relative to the sleeve and the clamp, and the
21 tolerance of the outer diameter of the bearing
22 region 6 and the inner diameter of the bushing 7 are
23 chosen to permit a degree of play between the two,
24 and allow rotation of the bushing 7 around the axis
25 of the sleeve 5.

26
27 The sleeve 5 has vanes 12 mounted on the upper large
28 diameter section. As best shown in Fig. 10, two
29 vanes 12 are mounted on each leaf of the sleeve, and
30 the vanes are spaced apart on the circumference of
31 the assembled sleeve 5 at equal distances, so that

11

1 the vanes 12 are arranged in diametrically opposed
2 pairs.

3
4 The vanes 12 have a generally sinusoidal "lazy-S"
5 shape with a lower scoop 12s, a generally axial mid-
6 region 12m, and an upper deflector portion 12d.

7
8 In side profile, the vanes 12 are generally arcuate
9 in the scoop and deflector regions, rising from the
10 plane of the sleeve 5 in a regular arc until a
11 plateau is reached at the mid-section 12m. Fig. 18
12 shows the side profile of a typical vane 12. The
13 vanes 12 project radially from the outer surface of
14 the sleeve 5, so as to create between adjacent vanes
15 12 a fluid path that is generally sinusoidal in
16 shape.

17
18 The bushing 7 has blades 15. Typically, there are
19 three blades arranged on each leaf of the bushing 7,
20 and typically these are circumferentially spaced at
21 equal distances, so that the blades 15 are arranged
22 in three diametrically opposed pairs, as best shown
23 in Figs. 6 and 7. Each blade 15 is arranged
24 generally parallel to the axis of the assembled
25 bushing 7, and in plan view, each blade 15 is in the
26 general shape of a foil or wing, as best shown in
27 Figs. 2 and 8. In detail, each blade 15 has a lower
28 end 15l that widens from the lowermost tip of the
29 blade to an apex 15a, from where it tapers through a
30 mid-section 15m, to an upper end 15u, and finally to
31 a slim point at the upper end. Shaping adjacent
32 blades like foils in this manner creates a flow path

1 between adjacent blades that rapidly narrows to a
2 throat at the level of the apex 15a of the blades,
3 and then gradually widens as the passage passes the
4 upper ends 15u of the blades.

5
6 As best shown in Fig. 9, the side profile of each
7 blade 15 rises from the plane of the bushing 7 at
8 the tips and is arcuate in the upper 15u and lower
9 15l ends, and forms a plateau in the mid-section
10 15m.

11
12 The nominal external diameter of the bushing 7 is
13 generally very close to the nominal external
14 diameter of the upper part of the sleeve 5, and also
15 matches that of the clamp 9, so that apart from the
16 vanes 12 and the blades 15, there are no upsets on
17 the outer surface of the apparatus.

18
19 The radial extent of the blades 15 typically exceeds
20 the radial extent of the vanes 12, so that the mid-
21 section 15m of the blades contacts the inner surface
22 of the bore in which the apparatus is deployed,
23 thereby spacing the vanes 12 from the inner surface
24 of the bore.

25
26 In preferred embodiments, the blades 15 are
27 integrally formed with the leaves of the bushing 7,
28 and in typical embodiments, the two leaves can be
29 cast or moulded each in a single piece with their
30 respective blades. Alternatively, the blades can be
31 formed separately and attached to the body of the
32 bushing 7 as required.

13

1 The vanes 12 can also be cast or moulded integrally
2 with the separate leaves of the sleeve, but in
3 preferred embodiments, the vanes 12 (and optionally
4 the blades 15) can be separately cast or otherwise
5 formed from the same or a different material, and
6 can be assembled with the sleeve prior to use in a
7 modular fashion.

8

9 One such arrangement is shown in Figs. 12 to 18.

10

11 In this embodiment, the sleeve 5 has a vane-
12 receiving portion 20, which comprises a region with
13 an increased inner diameter. Each vane 12 has a
14 base plate 12b attached to its radially innermost
15 face as shown in Fig. 15. The base plate 12b is
16 curved, with an outer diameter that matches the
17 inner diameter of a vane-receiving portion 20 of the
18 sleeve.

19

20 When the sleeve 5 is to be assembled with the
21 modular vanes 12, the radially outermost mid-portion
22 12m of each vane is offered to a vane-shaped slot 18
23 in the vane receiving portion 12, so that the mid-
24 portion 12m passes from the inner surface of the
25 sleeve 5 through the vane receiving slot 18, and
26 extends radially outward from the outer surface of
27 the sleeve 5. The curved radially outer face of the
28 base plate 12b of each vane 12 matches the inner
29 diameter of the vane receiving portion 20, and the
30 depth of each base plate 12b is chosen to match the
31 step between the nominal inner diameter of the
32 sleeve 5 and the nominal inner diameter of the vane

1 receiving portion 20, so that when the modular vanes
2 are assembled with the sleeve 5, the base plates 12b
3 are accommodated within the vane-receiving portion
4 20, and the inner diameter of the sleeve and base
5 place are contiguous. The assembled sleeve with
6 modular vanes 12 can then be clamped onto the
7 tubular T as previously described.

8
9 Modular vanes 12 give the advantage that worn vanes
10 can be replaced easily, and different sizes or
11 profiles of vanes 12 can be used with the same
12 sleeve body. Also, vanes of different materials or
13 properties can be provided on a generic sleeve 5,
14 and if desired, modular vanes 12 having different
15 characteristics can even be provided on the same
16 sleeve 5.

17
18 It will be appreciated that modular blades 15 can be
19 provided for the bushing 7 in the same way.

20
21 Typically the bushing 7 and blades 15 are formed
22 from a hard material such as a hard rubber or
23 plastic. Metals are also useful for the formation
24 of the bushing 7, and aluminium, zinc alloy, or
25 austempered ductile iron can be used for this
26 purpose.

27
28 The sleeve 5 and vanes 12 need not be formed from
29 the same material as the bushing 7 and blades 15,
30 and in preferred embodiments, metals or plastics can
31 be used for the vanes 12 and/or the sleeve 5.

32

15

1 In use, when the apparatus is clamped to a tubular T
2 such as a drill string that is being used to drill a
3 well, the device is typically deployed at regular
4 intervals along the bore, and can be used from a
5 position relatively close to the drill bit right up
6 to the top of the bore. The weight of the string T
7 typically forces the mid-portion 15m of the blades
8 15 against the inner surface of the wellbore, so
9 that the string is spaced away from the inner
10 surface of the wellbore by the radial extent of the
11 blades 15. Since the sleeve 5 is securely
12 rotationally fastened to the drill string T, the
13 sleeve 5 and hence the vanes 12 rotate in the
14 direction of arrow A in Fig. 1, ie clockwise when
15 viewed from the top of the string. However, since
16 the weight of the string is pressing the blades 15
17 against the inner surface of the wellbore, and since
18 the bushing 7 is rotatable on the bearing area 6,
19 the bushing 7 remains stationary relative to the
20 wellbore, and the sleeve and vanes 12 rotate
21 relative to the bushing 7 along with the string.
22
23 The radial dimensions of the blades 15 exceed those
24 of the vanes 12, and thus the vanes 12 are spaced
25 from the inner surface of the bore, and are not
26 impeded from rotating by contact with the inner
27 surface of the wellbore. The rotation of the vanes
28 12 and the speed of the string (typically 120-180
29 rpm with normal rotary drilling, but sometimes as
30 slow as 20 rpm with casing drilling) generates
31 turbulence in the drill fluid in the annulus between
32 the string and the wellbore. The sinusoidal

16

1 arrangement of the vanes 12 generates thrust in the
2 drill fluid in the region of the apparatus, and in
3 particular, the scoops 12s drive the drill fluid up
4 through the fluid passageways between adjacent
5 vanes, and the deflectors 12d accelerate it out of
6 the top of the fluid passage. In addition to
7 creating thrust in the fluid and pumping the fluid
8 from the lower end of the apparatus to the upper
9 end, this also creates turbulence in the fluid,
10 tending to break up clumps of drill cuttings, to
11 keep the fluid in a liquid phase.

12

13 The rapid rotation of the vanes 12 in the drill
14 fluid creates a pressure drop in the area between
15 the vanes 12 and the blades 15, which draws more
16 fluid up through the channels between adjacent
17 blades 15. As the fluid passes the apex 15a in the
18 channels between adjacent blades 15 on the
19 stationary bushing 7, it experiences a further
20 pressure drop created by the expansion in volume of
21 the fluid passageway as each blade narrows towards
22 its upper end. The pressure changes occurring as a
23 result of this speeds up fluid flow from the bit to
24 the surface, and also suspends cuttings in the
25 liquid phase, which makes it easier to return them
26 to surface.

27

28 An additional advantage of the non-rotating bushing
29 7 is that it reduces torque for rotation of the
30 string T within the hole, and the bearing surface
31 between the sleeve 5 and the bushing 7 is typically
32 lubricated by the drill fluid passing the apparatus.

1 In addition to this advantage, the smooth outer
2 surface of the blades 15, and particular the rounded
3 profile of the ends of the blades 15u and 15l, can
4 reduce drag while running in the hole, thereby also
5 reducing casing wear, and enhancing the penetration
6 of the drill bit. If the bushing 12 is manufactured
7 from materials having a low co-efficient of friction
8 then additional advantages in running in the hole
9 are also achieved. Notably, plastics, rubber and
10 zinc alloys give useful secondary advantages in this
11 respect.

12

13 The provision of the non-rotating bushing also
14 reduces drill string harmonics, and can help to
15 prevent differential sticking of the string.

16

17 Fig. 19 shows a further embodiment of apparatus for
18 mobilising drill cuttings in a well comprising a
19 sleeve 5', a bushing 7' and a clamp 9' similar to
20 that previously described for the first embodiment,
21 and assembled onto the string T in the same way.

22

23 The sleeve 5' has vanes 22 mounted on the upper
24 large diameter section. Only one vane 22 is mounted
25 on each leaf of the sleeve, and the vanes are spaced
26 apart on the circumference of the assembled sleeve
27 5' at equal distances, so that the vanes 22 are
28 diametrically opposed to one another.

29

30 The vanes 22 are generally straight, but are
31 attached to the sleeve 5' at an angle that is offset
32 with respect to the axis of the sleeve 5', from top

1 right to bottom left at around 5° wrt the axis.
2 Each vane 22 typically has a concave surface on one
3 side, typically that facing the direction of
4 rotation, as best seen in Fig. 20. The concave
5 surface typically acts as a scoop to create
6 turbulence in the fluid flowing up the annulus
7 between the sleeve 5' and the borehole. The radius
8 of curvature of the concave surface changes with the
9 axial position on the vane, as shown in Figs. 20 and
10 21, so that at the lower end of the blade (see B in
11 Fig. 19) the concave surface has a small curvature
12 with the radially outermost part of the blade being
13 nearly perpendicular to the tangent of the
14 circumference of the sleeve 5'; whereas at the upper
15 end of the blade (see A at Fig. 19) the radially
16 outermost part of the blade is more curved and
17 approaches a tangent to the circumference of the
18 sleeve 5'. This graduation in the radius of
19 curvature of the concave surface guides the fluid
20 flowing past the vane 22 towards the sleeve 5',
21 where turbulence and flow rates are highest, and
22 this keeps the cuttings in suspension for longer.

23

24 In some other embodiments of vanes, the change in
25 the radius of curvature is not required, and a
26 simple regular concave surface as shown in Figs. 22
27 and 23 will suffice.

28

29 The bushing 7' has blades 25. Typically, there are
30 three blades arranged on each leaf of the bushing
31 7', and typically these are circumferentially spaced
32 at equal distances, so that the blades 25 are

19

1 arranged in three diametrically opposed pairs. Each
2 blade 25 is offset at a 5° angle wrt the axis of the
3 assembled bushing 7', from top left to bottom right,
4 in an opposite configuration to the offset of the
5 vanes 22.

6

7 In side profile, as shown in Fig. 19, each blade 25
8 comprises a central plateau region and radially
9 lower ends. The width of the blades are consistent
10 throughout their length unlike the earlier
11 embodiments.

12

13 The nominal external diameter of the bushing 7' is
14 generally very close to the nominal external
15 diameter of the upper part of the sleeve 5', and
16 also matches that of the clamp 9', so that apart
17 from the vanes 22 and the blades 25, there are no
18 upsets on the outer surface of the apparatus.

19

20 The radial extent of the blades 25 typically exceeds
21 the radial extent of the vanes 22, so that the
22 plateau sections of the blades contact the inner
23 surface of the bore in which the apparatus is
24 deployed, thereby spacing the vanes 22 from the
25 inner surface of the bore.

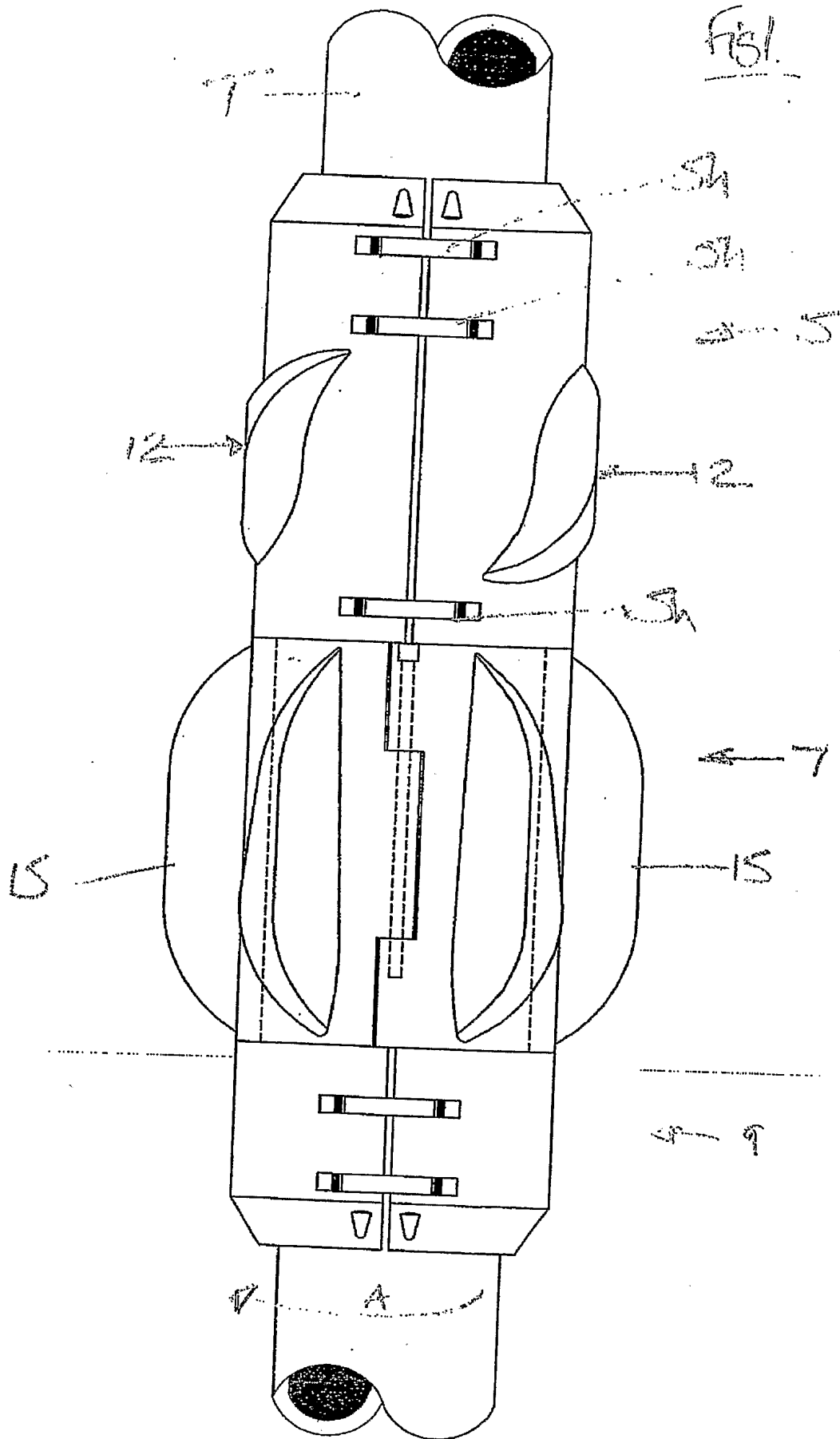
26

27 The blades 25 have profiled cross sections (i.e.
28 end-on views) in the form of an hour glass as best
29 shown in Figs. 20 and 21, with a wide root radially
30 innermost adjacent the bushing, a wide top at the
31 radially outermost plateau of the blade that bears
32 against the borehole wall, and a narrower cutaway

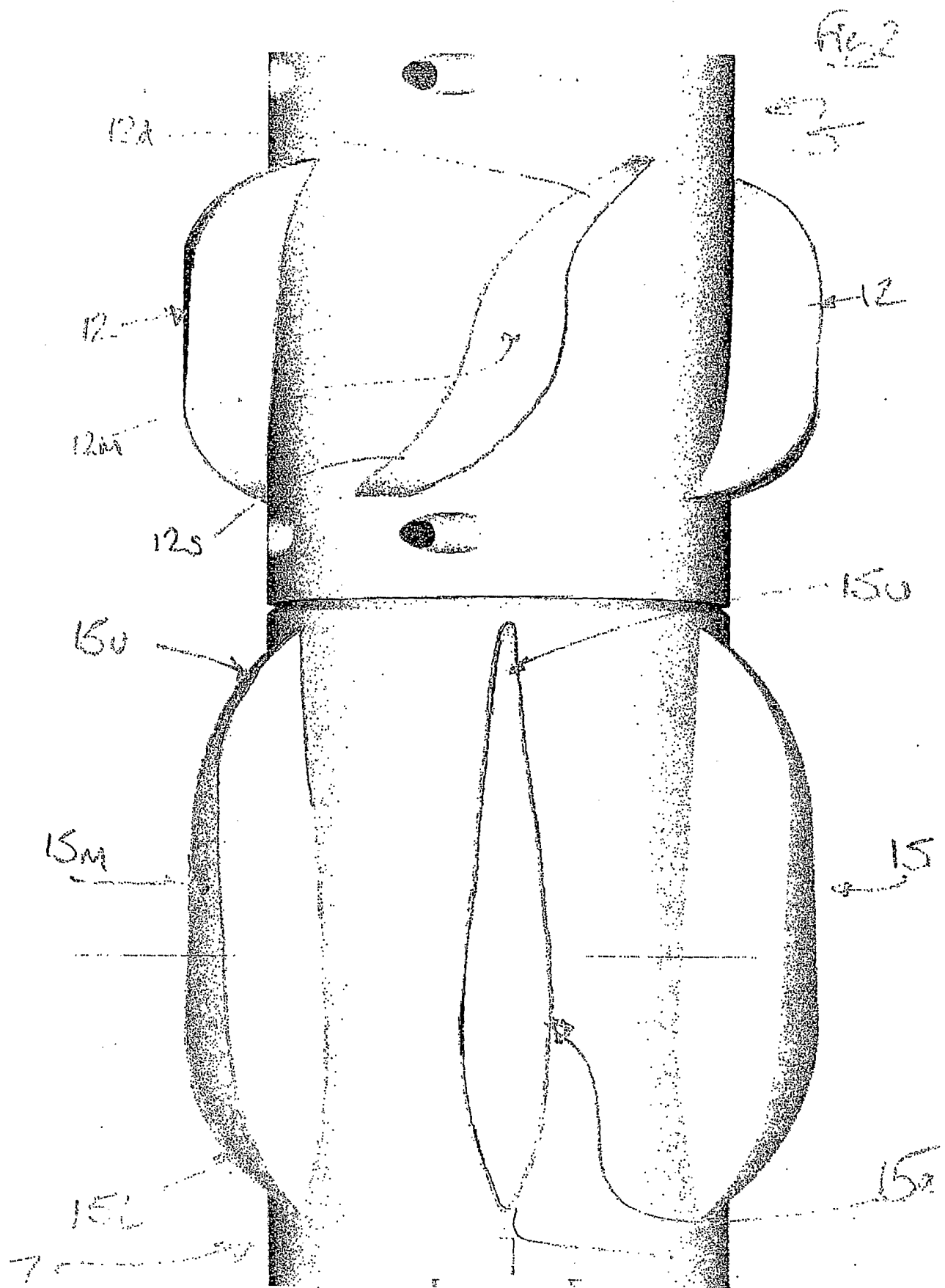
1 portion radially between the two to facilitate fluid
2 flow between the blades. This cutaway creates more
3 space for the fluid to pass between the blades, and
4 helps to avoid impedance of the fluid flow.

5
6 In use the operation of the second embodiment is
7 similar to the first, but the vanes 22 keep the
8 drill fluid and cuttings close to the wall of the
9 sleeve as the scoops drive the drill fluid up
10 through the fluid passageways between adjacent
11 vanes. In addition to creating thrust in the fluid
12 and pumping the fluid from the lower end of the
13 apparatus to the upper end, this also creates
14 turbulence in the fluid, tending to break up clumps
15 of drill cuttings, to keep the fluid in a liquid
16 phase.

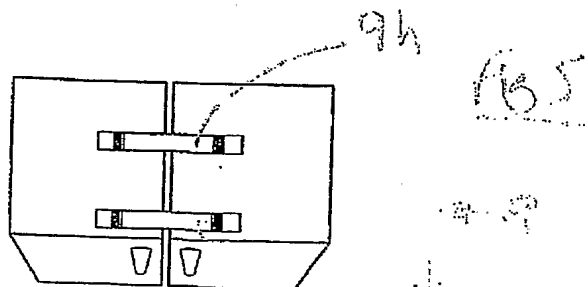
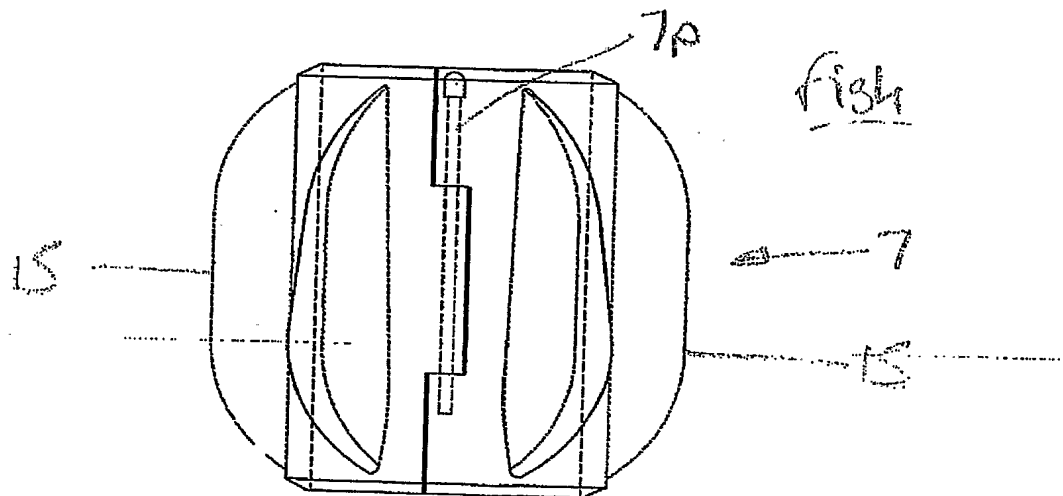
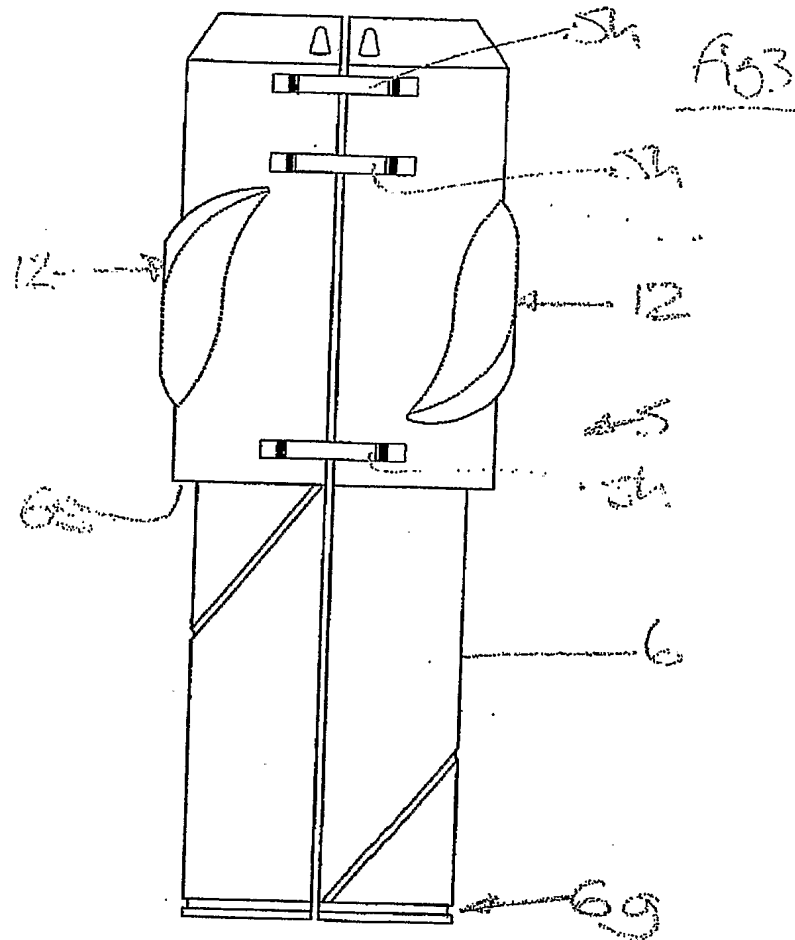
17
18 Modifications and improvements can be incorporated
19 without departing from the scope of the invention.
20



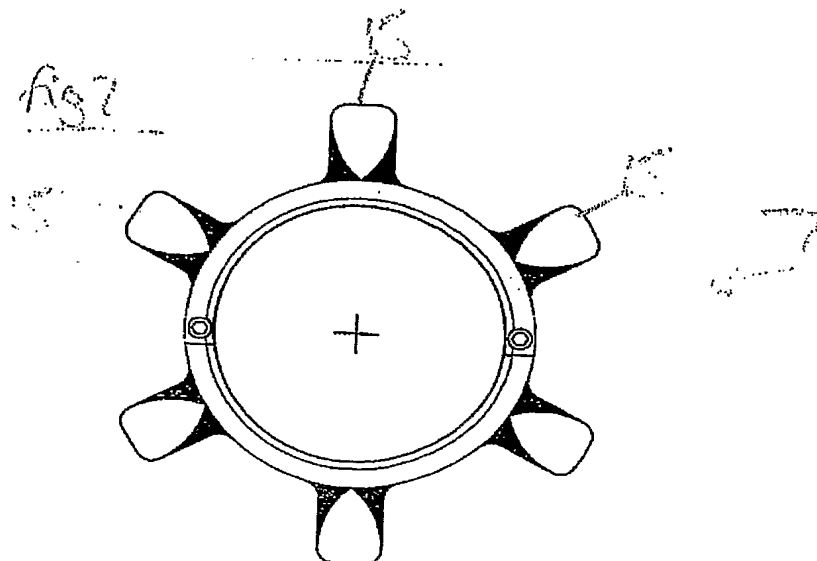
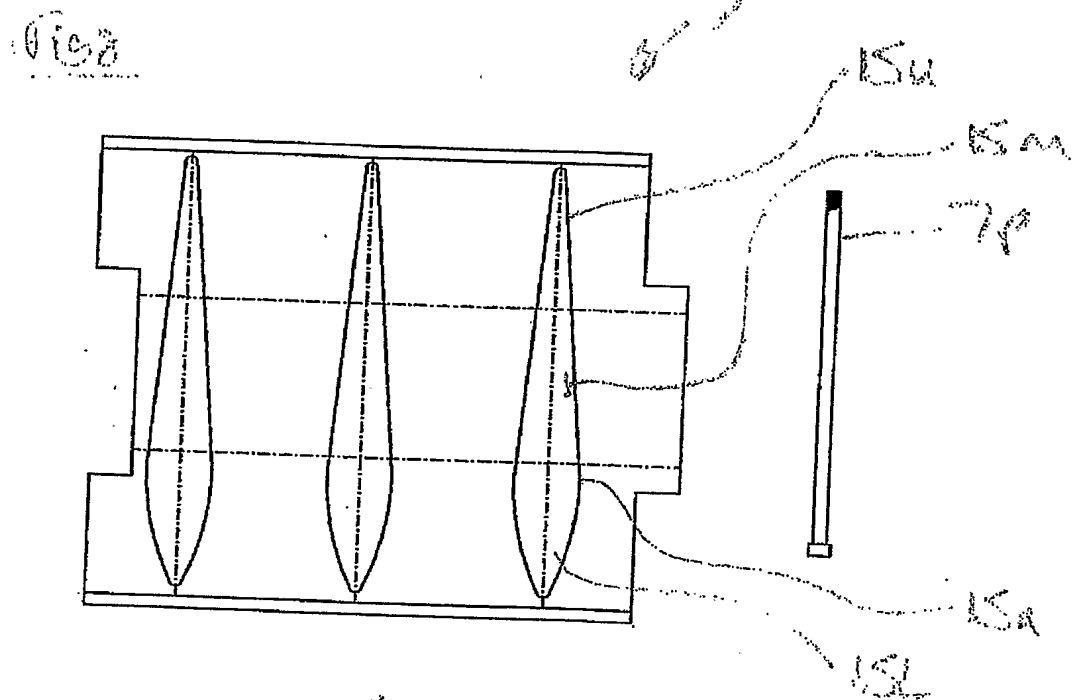
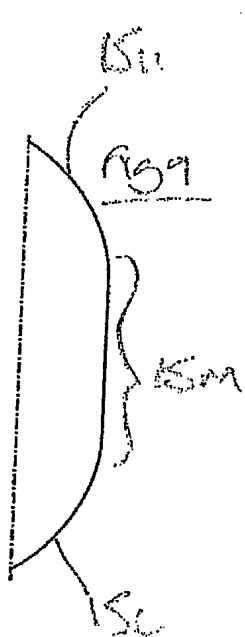
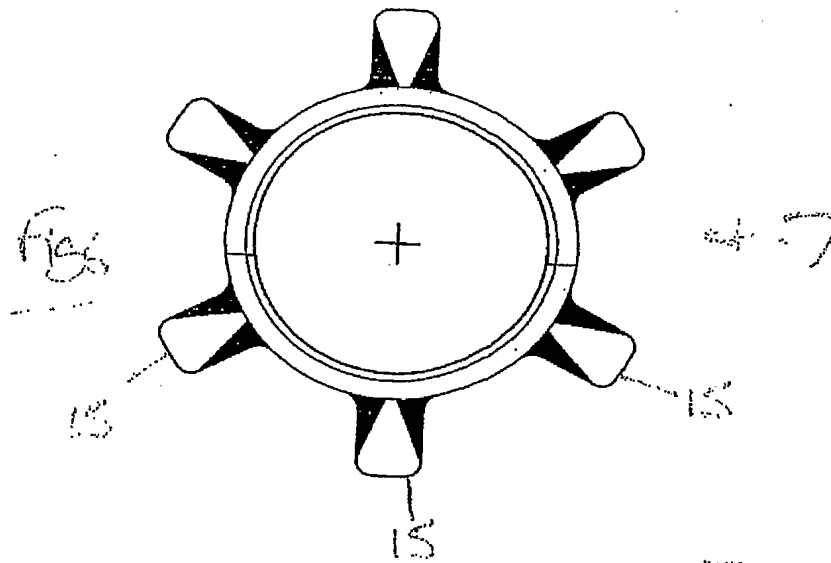














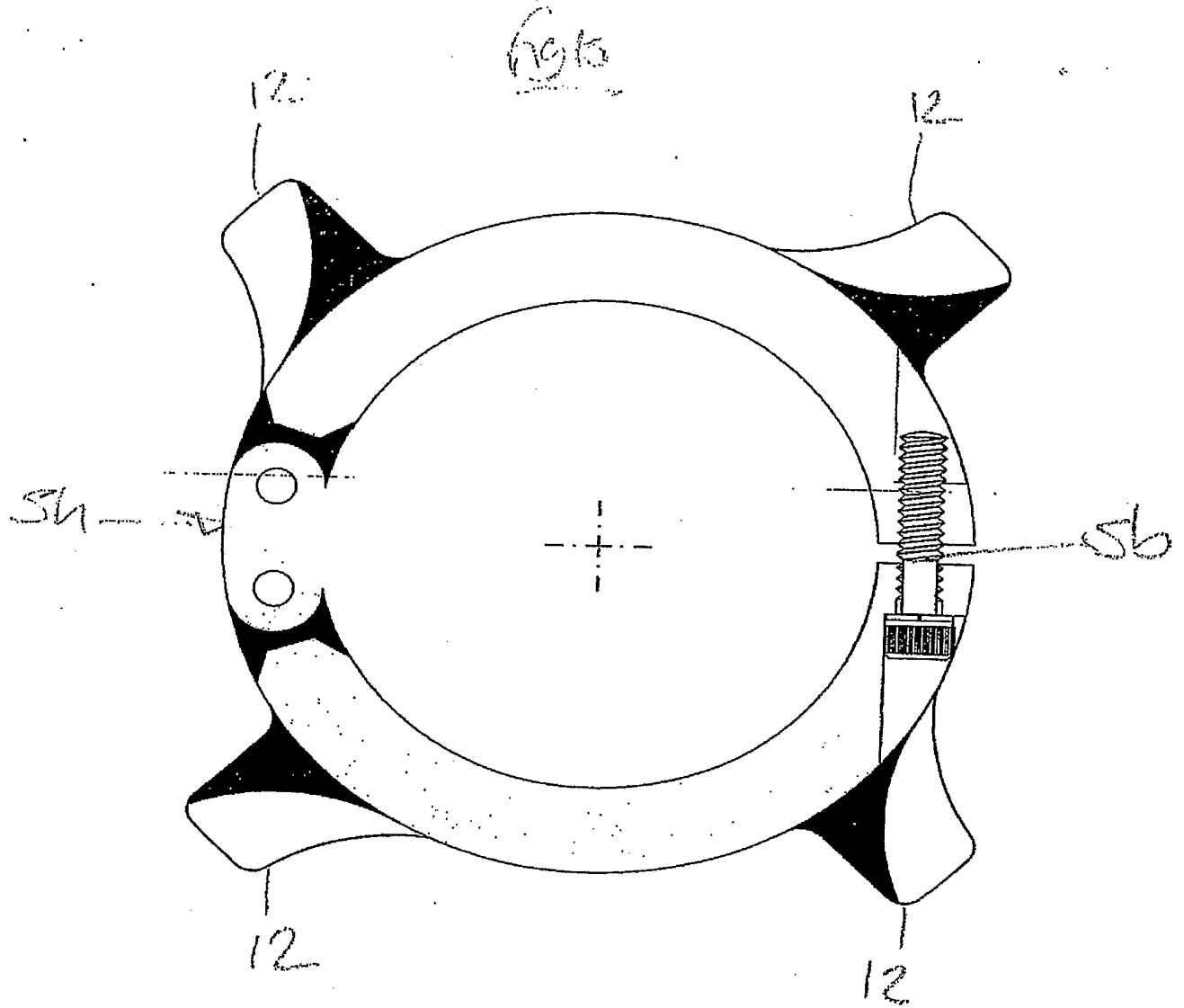
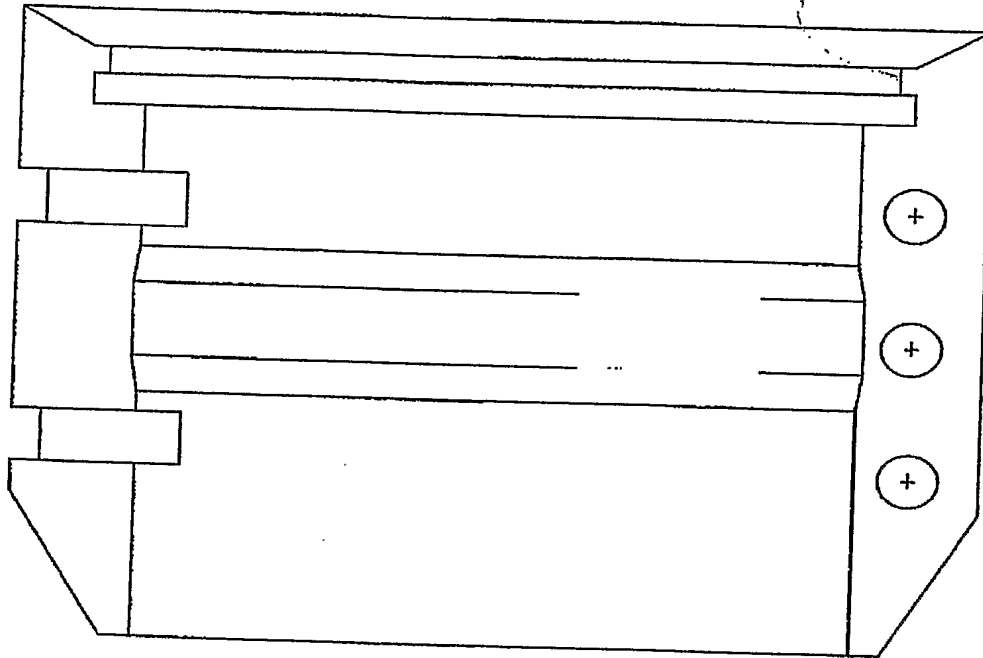




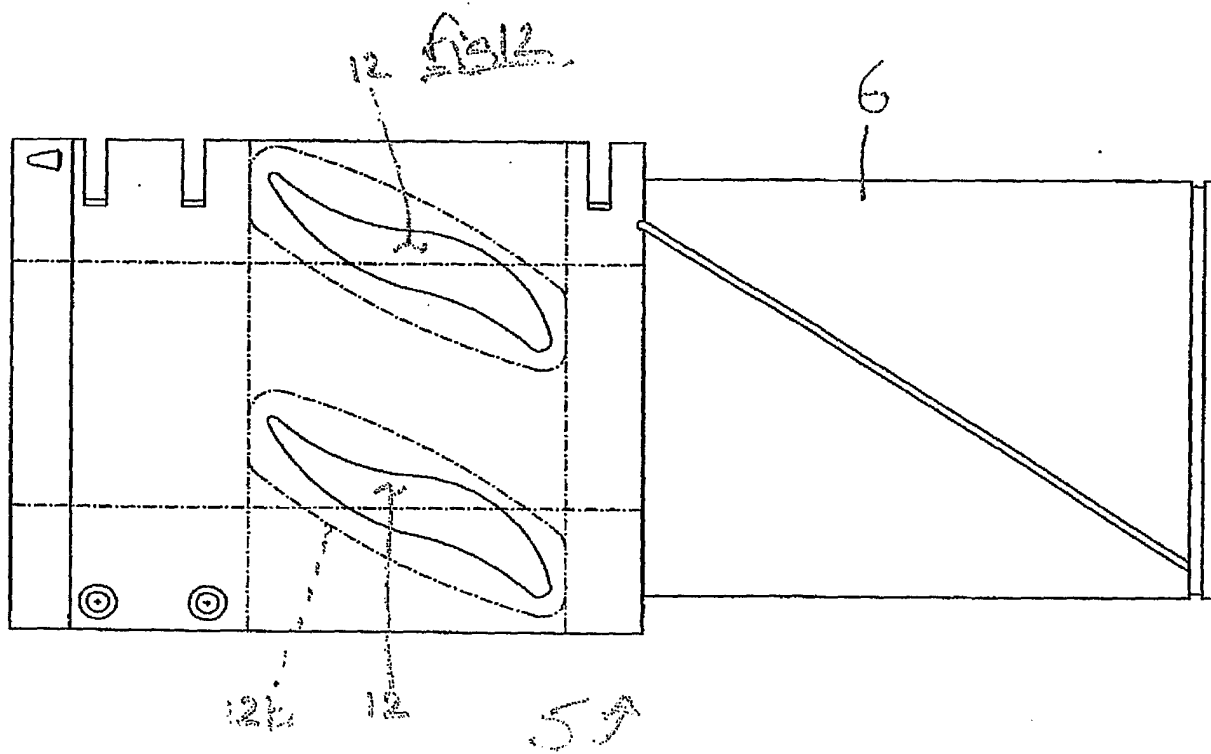
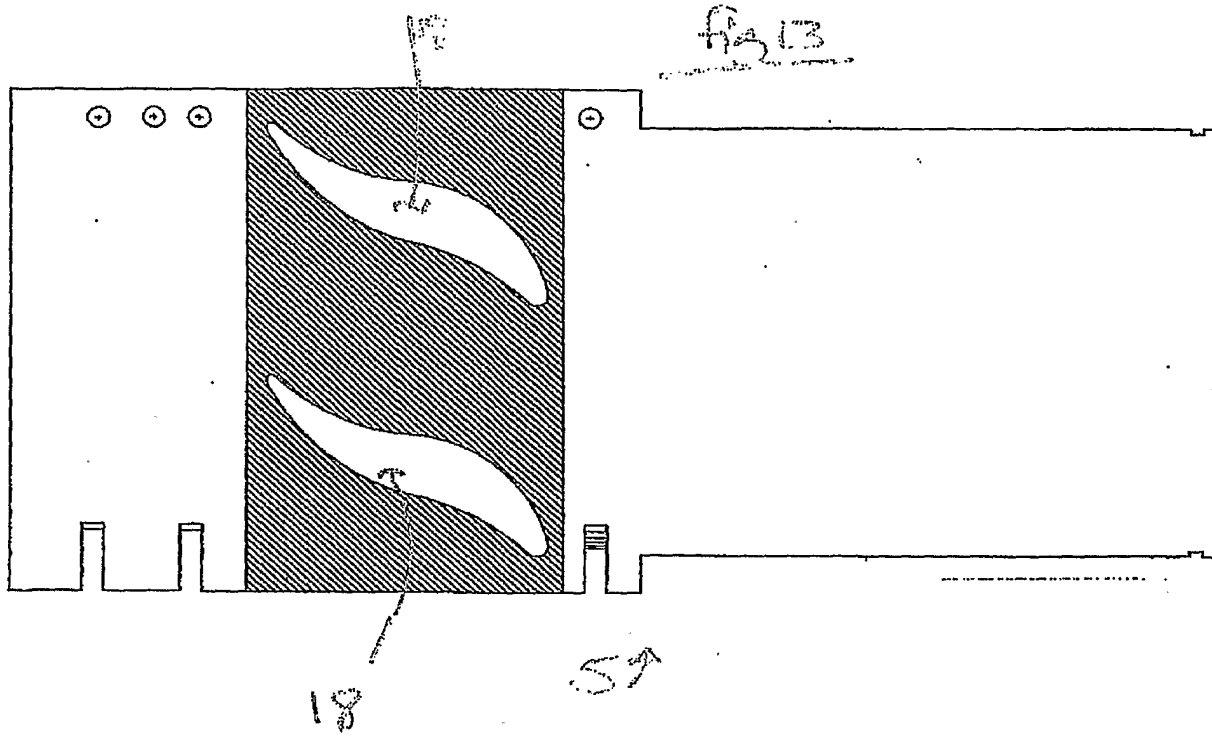
fig 11

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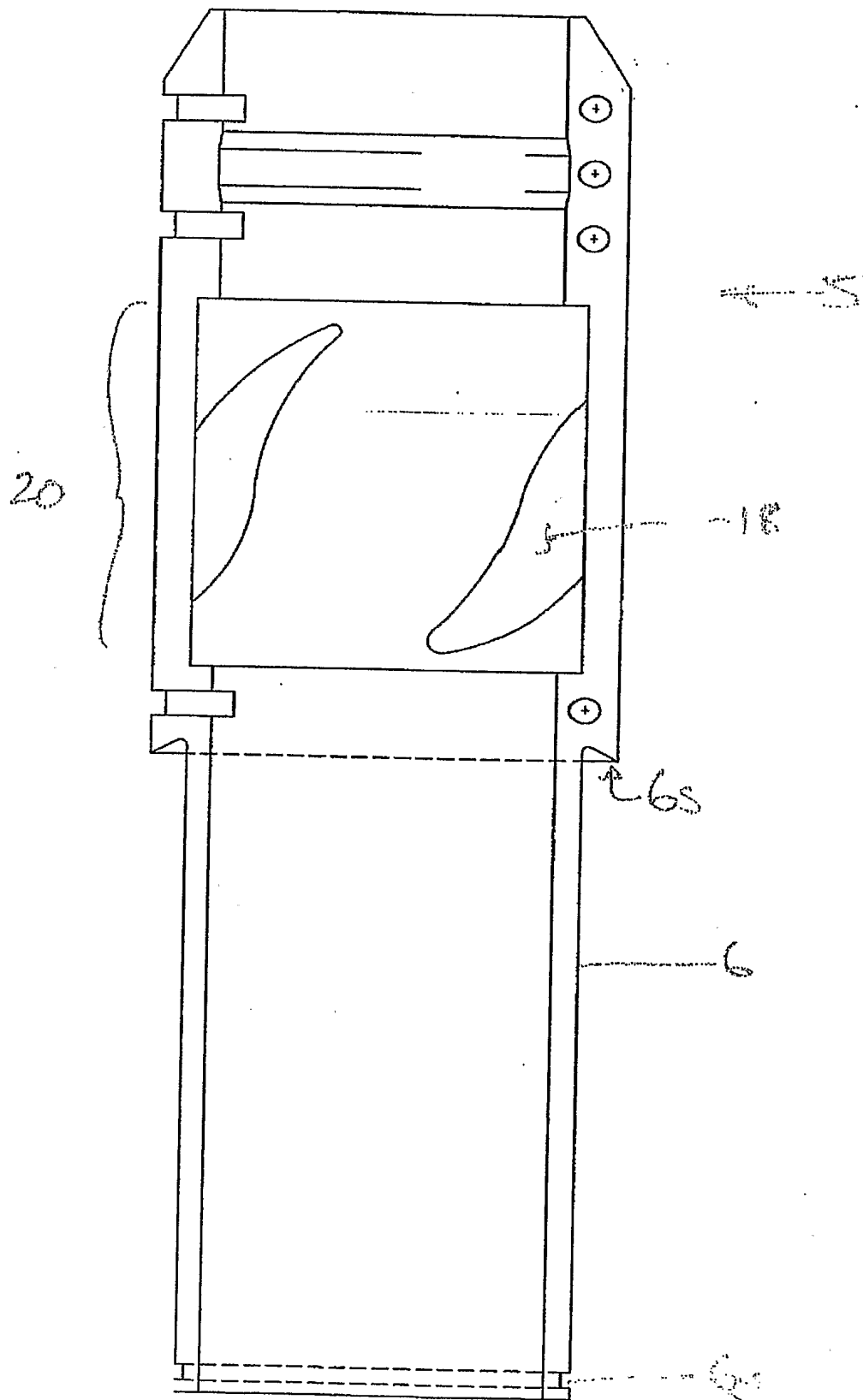


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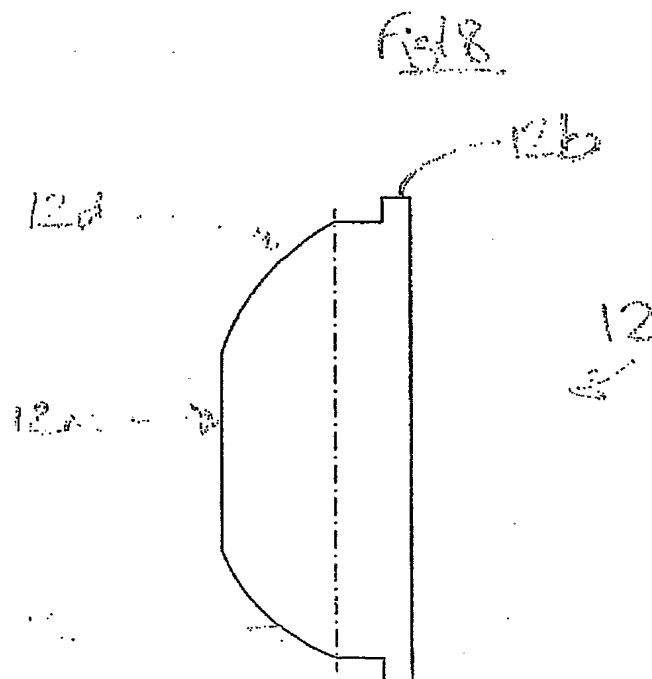
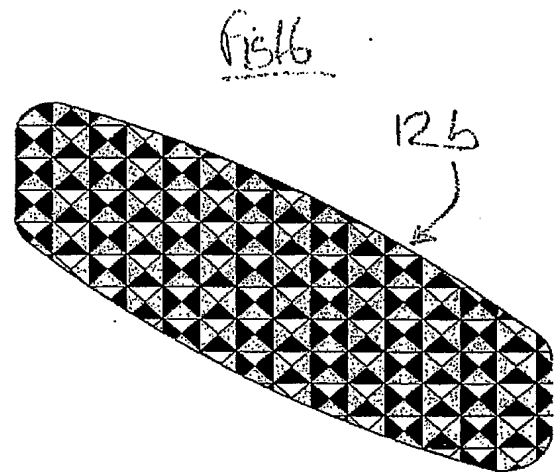
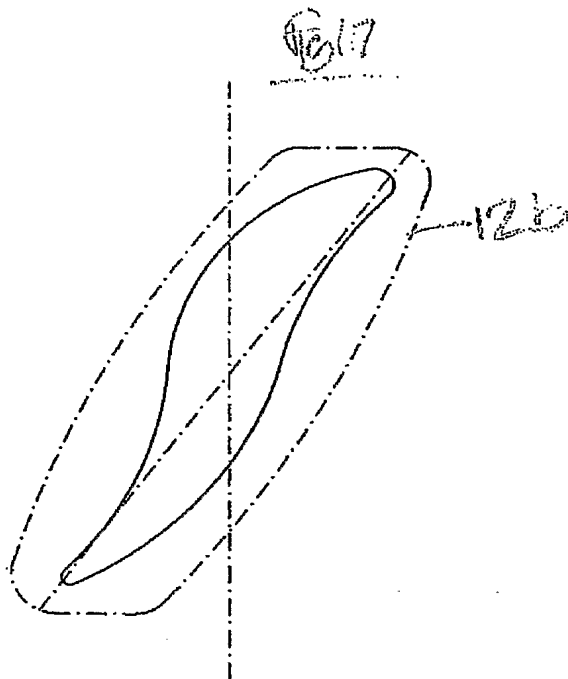
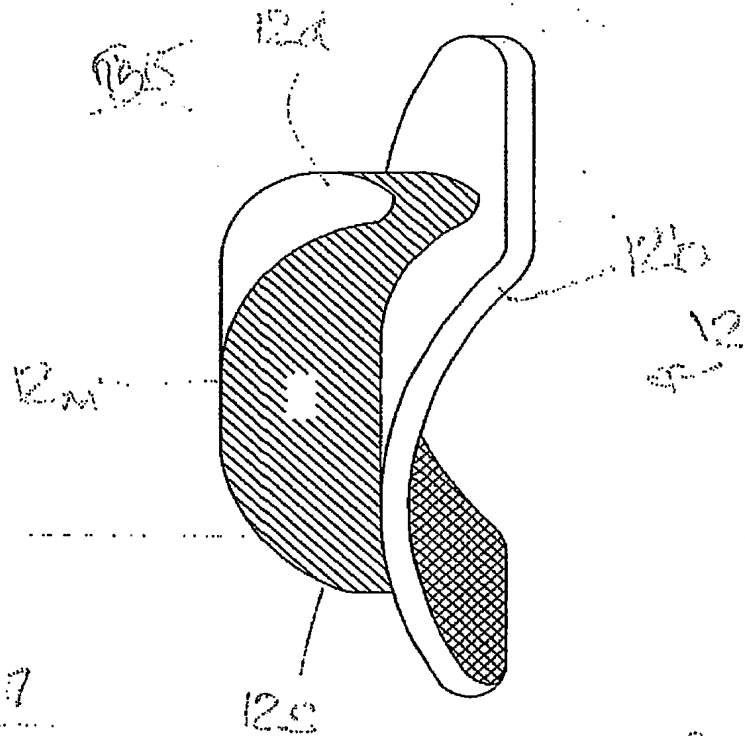




Fig 19

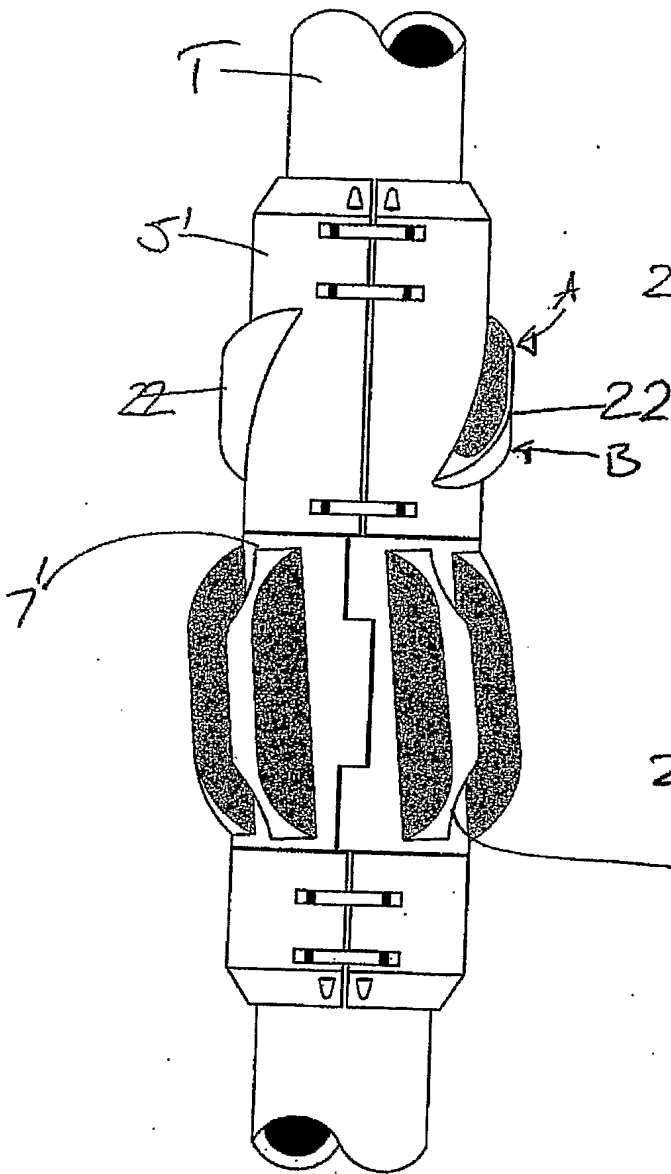


Fig 20

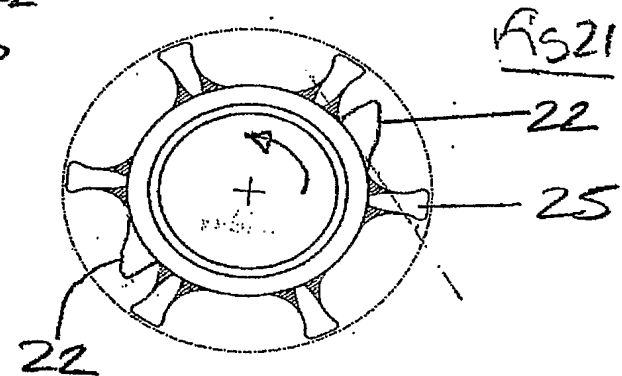
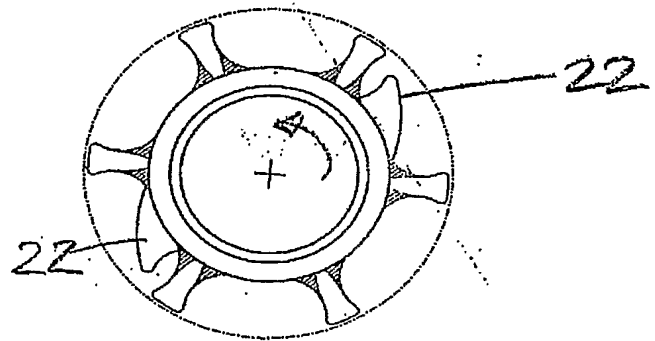


Fig 22

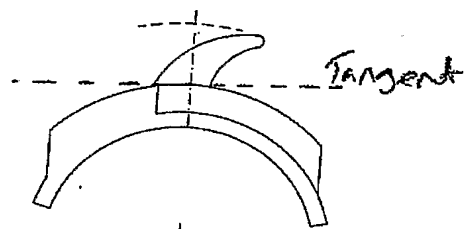
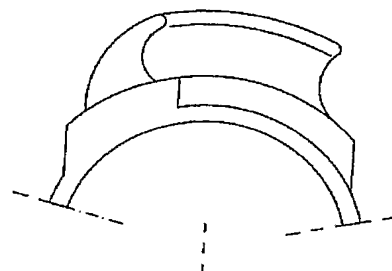


Fig 23





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